International Journal for the Scholarship of Teaching and Learning

Volume 7 | Number 2 Article 22

7-2013

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Keywords

Attitude, Inquiry, Biology, Laboratory, Undergraduate

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Introduction

To increase student learning in science and lower the attrition rate of science majors, many colleges and universities are reforming undergraduate biology laboratory courses (henceforth "labs") to be more student-centered (Sundberg, Armstrong, & Wischusen, 2005). For example, inquiry instruction has been advocated as a means of increasing achievement (Schroeder, Scott, Tolson, Huang, & Lee, 2007) and scientific literacy of students (National Research Council, 1996). Although increased student achievement and science literacy is a primary goal for most educators, student attitude towards science is also important because it impacts student learning (Oliver & Simpson, 1988).

Research suggests that attitude and achievement are closely linked (Koballa & Crawley, 1985); however, the precise relationship between them has been the subject of considerable debate. Some researchers contend that achievement is the causal factor affecting attitude towards science (Reynolds & Walberg, 1992). Others have suggested that attitude affects science achievement, and is a function of the nature of instruction (Simpson & Oliver, 1990). Negative attitudes in an undergraduate biology course have been associated with unfavorable student behaviors such as skipping classes, low in-class participation, and placing a greater emphasis on exam scores than learning of the course

https://doi.org/10.20429/ijsotl.2013.070222

content (Armbruster, Patel, Johnson, & Weiss, 2009). Regardless, studies have consistently shown that positive attitudes correspond with increased achievement in a wide range of science courses (Freedman, 1997; Mao & Chang, 1998; Nwagbo, 2006).

Reformed Instructional Models

Several recent studies have described how implementation of inquiry instruction positively affected student attitude in biology labs (Rissing & Cogan, 2009; Tessier, 2010); however, not all reformed courses result in positive student attitudes (Gogolin & Swartz, 1992). This study specifically investigated the effects of two modern reform strategies on student attitude toward biology lab: 1) inquiry and 2) explicit / reflective (ER) pedagogy. While scientific inquiry has been widely researched, including its potential effects on student attitude, far less is known about the effects of ER pedagogy in undergraduate science courses on student attitude.

Inquiry

Inquiry has been commonly used in revisions to science lab courses as a way to more closely mimic scientific practice. While all inquiry experiences have students engage in a valid scientific problem, inquiry instruction typically has a continuum of "openness," or student self-direction, from expository (instructor-centered) to open inquiry (student-centered) labs (Domin, 1999). Colburn (1997) ranked lab exercises on a scale from "verification" (level 0) to "authentic" (level 3). In a verification lab, students follow pre-determined methods and are guided by the teacher to a known result. Levels 1 and 2 involve increased student decision-making about the experimental design and data analyses, while authentic inquiry has students direct all parts of the investigation, from the question to the presentation of the results.

The challenges associated with transforming traditional lab courses to an inquiry style are significant (Sundberg, Armstrong, Dini, & Wischusen*,* 2000). However, some research suggests that the benefits of inquiry instruction can be worth the effort. Lord and Orkwiszewski (2006) found that non-majors in inquiry-based introductory biology labs had a more positive lab experience than students in matched non-inquiry labs. Results can also depend on the type of inquiry lab; chemistry students who participated in both guided inquiry and open inquiry labs expressed a more positive attitude toward the guided experiences because they were easier and required less effort (Chatterjee, Williamson, McCann, & Peck, 2009). On the other hand, a lack of significant difference in student attitude between traditional and reformed lab treatments was reported for freshman / sophomore-level students at two private liberal arts colleges (Hall & McCurdy, 1990) as well as 10^{th} grade students in a secondary-level biology course (Ajewole, 1991). Brickman, Gormally, Armstrong, and Hallar (2009) found that students exhibited resistance to reformed instructional models and that confidence increased more for students in a traditional version of a non-majors introductory biology lab course than those in an inquiry version of the course. It is interesting to note that those students felt they had learned more under the inquiry model even though they preferred non-inquiry instruction.

Nature of Science and ER

Nature of science (NOS) is the conceptual, philosophical, and methodological foundation of how scientists generate and acquire new knowledge (NRC, 1996). Inquiry instruction has traditionally been associated with NOS learning objectives because it was assumed that scientific practice led to a more informed NOS understanding; however, several studies have indicated that this is not the case (Bezzi, 1999; Fleming, 1998; Ryder, Leach, &

Driver, 1999). Undergraduates change little in their NOS understanding as they progress toward their degree (Dagher, Brickhouse, Shipman, & Letts, 2004), and even open inquiry college labs have little positive effect on student understanding of NOS (Roth & Roychoudhury, 1994).

The current recommendation is for inquiry instruction to be paired with an explicit / reflective (ER) pedagogy, where students participate in activities and peer discussions that address how NOS relates to their lab experiences (Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman, & Crawford, 2004). Coupling inquiry instruction with ER has resulted in increased understanding of NOS among K-6 teachers (Akerson, Hanson, & Cullen, 2007), and undergraduate pre-service science teachers in methods courses (Abd-El-Khalick & Akerson, 2004; Gess-Newsome, 2002), but there is a paucity of information regarding the implementation of an ER pedagogy in an undergraduate science class and how this relates to student attitude towards biology lab.

Rationale

Few studies have rigorously assessed whole course revisions comparing multiple matched labs covering identical content and skills with different instructional models (but see Berg, Bergendahl, Lundberg, & Tibell, 2003). Several studies have assessed student attitude as affected by a single lesson (Rissing & Cogan, 2009; Tessier & Penniman, 2006) or by a whole course revision (Ajewole, 1991), but did not use a previously published attitude instrument. This study is unique in that it implemented and carefully assessed a factorial design of lab treatments for ten weeks of a lab semester in which the exercises aligned identically except for instructional model.

The goal was to identify whether student attitude towards biology lab was differentially influenced by combinations of two instructional models: inquiry and ER. The study tested the hypothesis that instructional model has an effect on student attitude using a previously-validated quantitative instrument. Furthermore, it utilized open-ended questions to elucidate students' self-reported attitudes as well as the factors affecting these attitudes towards biology lab. It was predicted that three aspects of student attitude would be differentially affected by the instructional models: 1) the usefulness of biology lab, 2) confidence of success in biology lab, and 3) motivation to overcome the challenges in biology lab (i.e., "effectance motivation").

Methods

Course Description and Study Population

Participants were recruited from an introductory biology course offered at a mid-sized, Midwestern university during the fall semester of 2008. This 4 credit, mixed-majors course included both a lecture (3 credits) and lab component (1 credit) and was the first of a two-semester sequence. The overall enrollment of the course was approximately 670 students, primarily freshmen. Course content included ecology, evolution, genetics and biodiversity and was delivered in 3 lecture sections and 31 associated lab sections. The lab sections were taught by a total of 17 graduate teaching assistants. This study was designed for and implemented exclusively in the lab component of the course; the lecture component was not altered.

Experimental Design

A 2 x 2 factorial design was used to test the effects of the instructional model treatments and their combinations on student attitude one of four types of biology lab: IN (henceforth, IN) with explicit / reflective (ER) pedagogy (IN+ER; n = 194, 9 sections), IN without ER (IN; n = 142, 7 sections), expository (EX) with explicit / reflective pedagogy (EX+ER; n = 123, 7 sections), and expository without ER (EX; n = 143, 8 sections). Each treatment combination was randomly assigned to the available lab sections, and students registered for a lab section without knowing their treatment combination.

Five new IN labs, comprising 10 of the 12 lab weeks of the semester, were created for the project. Lab activities addressed topics relevant to lecture, but were not linked to the weekly lecture content. Each lab introduced students to a scientific problem by providing general background information but did not reveal predetermined answers to the problem. Students were provided a set of materials and challenged to develop a hypothesis and experimental design to investigate the problem. They then carried out this experiment, analyzed the data, and reported the results in the form of a written report. Although TAs guided students through this process, they were instructed to not give students answers that may subvert the IN process. According to Colburn (1997), this constituted a "level 2" IN experience.

The expository labs were generated from the IN labs by adding predetermined hypotheses, lists of methods, data sheets, and anticipated results for each investigation. TAs were instructed to answer any student questions about the expository lab activity, including confirming correct results. Therefore, these expository labs were aligned in problem, content, and basic procedures with the IN labs, yet maintained the differences in instructional model. The IN and expository labs were evaluated by the project advisory committee to verify these differences between treatments. Students received separate versions of the lab manual, each specific to the respective IN or expository treatment. While it is impossible to know for certain if students from different treatments compared lab manuals, most participants made statements indicating they were unaware lab sections were taught with different instructional models (unpublished data).

The ER pedagogy was implemented as a discussion in designated IN + ER and EX + ER labs under the direction of the TA (Bautista & Schussler, 2010; Schussler & Bautista, 2011). The IN and expository sections assigned as +ER received the same ER treatment every week. The ER treatment focused on five aspects of NOS: tentative, observation/inference, creativity, theory-laden, and myth of the scientific method. These aspects were chosen based on the recommendation of the project advisory board as the ones most likely to be improved in an introductory lab. To implement ER, one or two NOS aspects were chosen by the project directors for each lab, depending on the activities and topics. Discussion questions were created to probe student understanding of those aspects as they related to the lab. These discussions lasted anywhere from 5-20 minutes depending on the aspects and the TA. Students in non-ER labs did not explicitly discuss any of the NOS aspects.

Instructors

All TAs participated in a two-day workshop prior to the start of the semester to inform them about NOS and IN instruction. Teaching assignments were then made to the treatments based on teaching experience, and each TA's personal preferences. This ensured that TAs did not teach a treatment combination they were uncomfortable with and that each treatment combination was taught by both experienced and first-year TAs. Each TA taught a maximum of two lab sections of the same treatment combination. During the semester, IN and expository TAs attended separate weekly lab preparation meetings. The nine TAs who implemented the ER treatment labs attended a one hour ER preparation session approximately every two weeks in which the NOS objectives and discussion questions for each lab were discussed and clarified.

Implementation of the treatments was verified through 40 lab observations conducted by the project leaders. There were no documented instances of non-ER TAs having classroom discussions with students about NOS, or of IN TAs who implemented the laboratories in ways which were inconsistent with inquiry instruction. Additional information about the delivery of the labs can be found in Bautista and Schussler (2010) and Schussler and Bautista (2011).

Due to a request by the university human subjects board, which approved all procedures used in this study, the assessment for all lab sections was uniform and included pre-lab exercises, quizzes, lab reports, and midterm and final exams. Although ER students did have to write about NOS in their lab reports, these parts were only graded on completion in order to keep point totals between treatments uniform.

Data Collection

A mixed methods approach was used in this study whereby attitudinal aspects were assessed using both quantitative and qualitative measures. Comparing the congruence of data collected by the different methods of analysis allowed for the "triangulation" of factors that affected attitude in the labs (Oliver-Hoyo & Allen, 2006).

Quantitative Data

To assess student attitude for this project, a modified version of the Fennema-Sherman Mathematics Attitude Scale (FSMAS) was used (Fennema & Sherman, 1976). This instrument was chosen because it has been shown to yield reliable data (Melancon, Thompson, & Becnel, 1994). The FSMAS was originally designed to assess students' attitudes towards mathematics but has been used successfully to assess attitudes in chemistry by substituting the word "chemistry" for "mathematics" throughout the instrument (Turner & Lindsay, 2003).

For this study, the three FSMAS sub-scales (12 questions each) for confidence, usefulness and effectance motivation (the motivation to overcome challenges; White, 1959) were used. In each of the 36 questions, the word "mathematics," was replaced with the words "biology lab" (examples are shown in Table 1). Half of the questions in each sub-scale are worded in the positive (e.g., I like biology lab) and the other half are negatively worded (e.g., I dislike biology lab). The choices for each question were Likert style (5-point rating scale from strongly agree – strongly disagree). In addition to the 36 survey questions, individuals reported their year in school, gender, ethnic background, major, career plans, and lab section.

Table 1. Examples of questions modified from three sub-scales of the Fennema-Sherman Mathematics Attitude Scales (FSMAS). In each question, the word "mathematics" was replaced with "biology lab". Example questions were chosen to reflect the range of questions for each subscale; both positively and negatively worded examples are provided.

Sub-scale		Sample Questions
Confidence		
	Positive	I can get good grades in biology lab
		I am sure I could do advanced work in biology lab
		I have a lot of self-confidence when it comes to biology lab
	Negative	I don't think I could do advanced biology lab
		I'm not the type to do well in biology lab
		For some reason even though I study, biology lab seems unusually hard for me
Usefulness		
	Positive	I'll need biology lab for my future work
		I study biology lab because I know how useful it is
		Knowing biology lab will help me earn a living
	Negative	Biology lab is of no relevance to my life
		Biology lab will not be important to me in my life's work
		I see biology lab as a subject I will rarely use in daily life as an adult
Effectance Motivation		
	Positive	Biology labs are enjoyable and stimulating to me
		When a biology lab problem arises that I can't immediately solve, I stick with it until I have the solution
		Once I start trying to work on a biology lab I find it hard to stop
	Negative	The challenge of biology lab does not appeal to me
		Biology labs are boring
		I would rather a person give me the solution to a difficult biology lab problem than have to work it out for myself

Undergraduate participants for the quantitative portion of this study were recruited in their regular lab classroom during the first and 15th week of the semester. Students were informed of the goals of the study and asked both verbally and in writing by the authors, or one of three project assistants, to voluntarily complete the 36 question paper and pencil instrument. No incentives were provided to students for their participation and participants filled out the surveys with the understanding that their responses were being recorded via a self-selected code and not their name, and that their instructors would not see their responses.

Qualitative Data

To further explore the relationship between instructional model and student attitude, students were asked to voluntarily and confidentially self-report, via an on-line open-response survey during the 10th week of the semester, what factors influenced their attitude in biology lab. The on-line survey (questions in Table 2) asked students to comment on their overall attitude, confidence, perception of usefulness, and effectance motivation related to the biology lab, as well as which factors they felt most strongly influenced each of these constructs. Because students may not have understood what was meant by "effectance motivation," students were asked to comment about what they believed were the greatest challenges in lab as one question and then in a second question to discuss how motivated they were to overcome these challenges.

Table 2. Summary of qualitative questions asked via internet-based survey instrument. All questions on the instrument are presented here in shortened form.

Attitude Aspect	Questions
Overall Attitude	Please describe your overall attitude toward your biology lab up to now. If you can, please describe a situation that sums up why you feel the way you do about lab.
Confidence	How confident are you about your ability to succeed in lab? Please provide examples of how you have felt confident, or have not.
	What factors do you think most strongly influenced your level of confidence?
Usefulness	How useful to your academic and /or professional career do you think what you've learned in lab has been? Please provide examples.
	What factors do you think most strongly influenced your perception of how useful lab is to your career?
Effectance Motivation	What do you think is (are) the greatest challenge(s) presented by lab?
	How motivated are you to overcome this (these) challenge(s)?
	What factors have influenced your level of motivation to overcome the challenges of your biology lab?

Data Analysis

Likert responses to the modified FSMAS instrument were assigned numeric values from 0 – 4, where higher values corresponded with more positive attitudes (e.g., strongly disagree = 0, strongly agree = 4). The scale for the negatively worded questions was reversed so that the same standard of 0 for less positive and 4 for more positive attitudes was maintained. Data from 68 individuals who were suspected of not taking the survey seriously (e.g., responding "strongly agree" to all questions, including the negative-reversed items) were deleted from the pool of 425 participants who completed both the pre- and post- surveys.

For each participant, total scores for each sub-scale were calculated by summing the Likert scores, yielding a maximum score of 48 per sub-scale. These were calculated for both pre- and post- surveys and tested separately for reliability via Cronbach's α. To compare changes in each sub-scale (e.g., confidence subscale) among treatment combinations, Relative Change in Attitude (RCA) for each sub-scale was quantified as:

$$RCA = [-(\text{Pre-survey Score} - \text{Post-survey Score}) / \text{Pre-survey Score}]$$

RCA was analyzed for each sub-scale using a mixed-model ANOVA with gender, career plans, treatments, and interactions as fixed effects, and lab section as a random effect. Lab section was treated as a random effect to account for variation among classroom variables such as student population characteristics as well as the TA. One-way ANOVA was used to test for differences among demographic variables (e.g., lab section, etc.) for each sub-scale. For this test, a Bonferroni Correction was used to address the problem of multiple comparisons and the rejection level was set at $p \leq 0.016$ (0.05 / 3). In all other statistical tests, a $p \leq 0.05$ acceptance level was used.

The qualitative on-line survey data underwent inductive analysis according to the methods of Corbin and Strauss (1990) in which no predetermined themes or codes were used in the analysis. Students' written responses to each of the open-ended survey questions (regarding overall attitude, confidence, usefulness, challenges, and motivation to overcome those challenges) were read repeatedly by each of the authors independently and an initial list of themes was identified. The authors then discussed and organized these initial themes until a list of overarching themes and sub-themes for each question was agreed upon. This list of themes was then used to code participant responses to each attitude subscale. Within each response to a given question, (e.g., What factors contributed most to your overall attitude?), an individual respondent was recorded as referencing a given theme only once regardless of the number of times the participant mentioned the theme. For each question, the frequency of responses for each theme is presented as a proportion of the participant population. For example, of the 137 participants, 58 made comments regarding "grades" influencing their attitude; therefore, the prevalence of this theme for this question was 42%. The results below are presented as overarching themes, followed by a description of how each of the themes influenced each sub-aspect of attitude (i.e., confidence, etc.).

Results

Quantitative Assessment of Attitude towards Biology Lab

Participant Population

A total of 357 matched pre- and post-surveys of student attitude were used in the analyses. All treatment combinations were represented, with 34% of participants from IN + ER, 23% from IN, 21% from EX + ER, and 22% from EX sections. The sample consisted of 59% females and 41% males. Fifty percent of participants self-reported their major as zoology, 13% claimed microbiology, and less than 1% claimed botany, while 24% of participants stated they were "other science" majors. Non-science majors accounted for 6% and undecided students composed 6% of the sample population. The sample consisted of 71% first-year students and 17% second-years, with third and fourth year students making up 8% and 4%, respectively. Caucasians comprised 86% of the sample, African-Americans and Asian-Pacific Islanders comprised 4% and 5%, respectively, Hispanics comprised 1%, and other ethnicities were 3% of the sample.

Confidence

The confidence sub-scale was reliable when administered as both a pre- (Cronbach's $\alpha=0.91$) and post-survey ($\alpha=0.92$). RCA for confidence was slightly positive in the EX treatment combination (0.01 ± 0.26) and slightly negative in the EX+ER (-0.02 ± 0.33), IN

(-0.08 + 0.26), and IN+ER (-0.04 ± 0.29) treatment combinations (Figure 1a); however, there were no significant differences in confidence RCA for the IN (n=205, F=2.37, p=0.14) or ER treatments (n=152, F=0.04, p=0.84), their interaction (F=0.07, p=0.80), or gender (F=0.74, p=0.48). Relative change in confidence was found to be significantly different among lab sections (Table 3) using a one-way ANOVA with lab section as a fixed effect (n=357, F=2.53, p≤0.001).

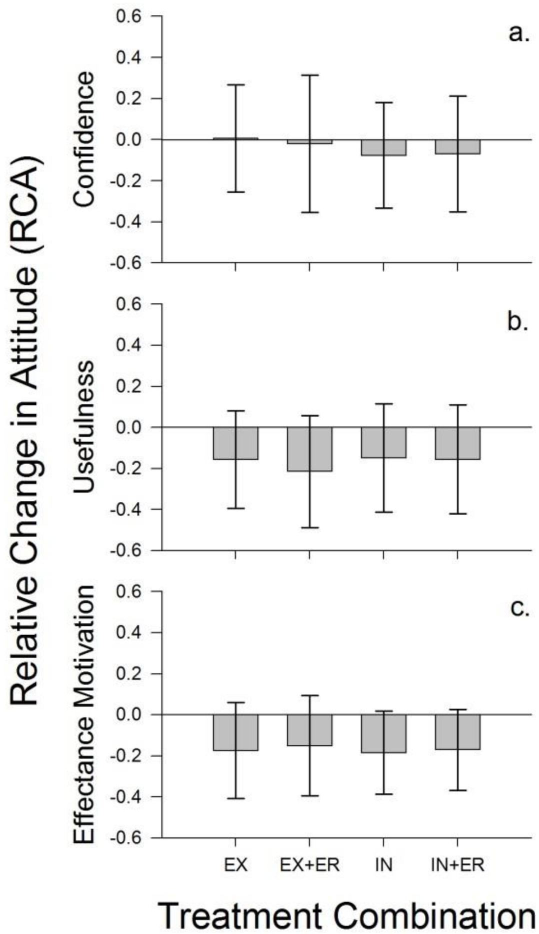

Figure 1. Relative change in attitude (RCA) for the confidence, usefulness, and effectance motivation sub-scales modified from the Fennema-Sherman Mathematics Attitude Scales (FSMAS). Data are reported for four instructional model treatment combinations: expository alone (EX; n=75), expository with explicit and reflective (EX+ER; n=77), inquiry alone (IN; n=82), and inquiry with explicit and reflective (IN+ER; n=123). Error bars represent one standard deviation.

Table 3. Relative change in attitude (RCA) by treatment combination and selected lab section for each of the three modified sub-scales of the FSMAS for expository (EX), expository with explicit and reflective (EX+ER), inquiry alone (IN) and inquiry with explicit and reflective (IN+ER) instructional model treatment combinations. Rank represents the lab section with the highest (HI) and lowest (LO) RCA for confidence, the only sub-scale with significant (*** p≤0.001) differences among laboratory sections as identified with 1-way ANOVA. Error represents standard deviation.

Treatment Combination	Rank	n	Confidence***	Usefulness	Effectance Motivation
EX	HI	9	0.23 ± 0.35	-0.09 ± 0.26	0.03 ± 0.23
	LO	11	-0.15 ± 0.33	-0.22 ± 0.27	-0.28 ± 0.24
EX+ER	HI	7	0.27 ± 0.64	-0.10 ± 0.25	-0.07 ± 0.20
	LO	11	-0.32 ± 0.20	-0.34 ± 0.28	-0.32 ± 0.22
IN	HI	15	0.04 ± 0.29	-0.04 ± 0.22	-0.08 ± 0.20
	LO	6	-0.24 ± 0.20	-0.24 ± 0.26	-0.26 ± 0.22
IN+ER	HI	17	0.10 ± 0.39	-0.06 ± 0.20	-0.06 ± 0.14
	LO	12	-0.19 ± 0.28	-0.30 ± 0.28	-0.32 ± 0.24

Usefulness

The usefulness sub-scale was also reliable when administered as both a pre- (Cronbach's α=0.93) and post-survey (α=0.95). RCA for perception of usefulness was negative in all treatment combinations, most greatly in the EX+ER treatment combination (-0.22 ± 0.27), followed by the EX (-0.16 ± 0.24), IN+ER (-0.16 + 0.27), and IN (-0.15 ± 0.26) treatment combinations (Figure 1b); however, no significant differences in relative change in usefulness for either the IN (n=205, F=1.32, p=0.25) or ER treatments (n=152, F=1.48, p=0.22), their interaction (F=1.08, p=0.30), gender (F=0.23, p=0.79), or career plans (F=0.70, p=0.67) were found. Relative change in usefulness was not significantly different among lab sections (Table 3) using a one-way ANOVA with lab section as a fixed effect (n=357, F=1.01, p=0.46).

Effectance Motivation

The effectance motivation sub-scale was reliable when administered as both a pre- (Cronbach's α =0.87) and post-survey (α =0.90). RCA for effectance motivation was negative in all treatment combinations; most greatly in the IN treatment combination (-0.19 ± 0.20), followed by the EX (-0.17 ± 0.23), IN+ER (-0.17 ± 0.20), and EX+ER (-0.15 ± 0.25) treatment combinations (Figure 1c), however, no significant differences were found in relative change in effectance motivation for either the IN (n=205, F=0.18, p=0.68) or ER treatments (n=152, F=0.10, p=0.76), their interaction (F=0.10, p=0.92), gender (F=2.03, p=0.13), or career plans (F=0.69, p=0.69). Relative change in effectance motivation was not significantly different among lab sections (Table 3) using a one-way ANOVA with lab section as a fixed effect (n=357, F=1.66, p=0.02).

Factors Affecting Student Attitude
One hundred thirty-seven individuals participated in the qualitative survey and of these, 102 provided demographic information. Most participants were from IN+ER lab sections (42%) with the fewest from EX+ER sections (11%). Participants from the IN and EX sections accounted for 19% and 28% of the sample, respectively. Forty-seven percent of the students stated their major to be zoology, 19% claimed microbiology, 27% claimed other science, 2% were botany, and 5% were undecided. Non-science majors made up 1% of participants. The sample consisted of 30% males and 70% females, with 73% first-year students and 17% second-year, 4% third-year, and 6% fourth year students. Caucasians comprised 91% of the sample, Asian-Pacific Islanders and African Americans comprised 4% and 3%, respectively, and Hispanic and other ethnicities were each 1% of the sample.

The majority of students (45%) indicated that their overall attitude toward biology lab was negative, 29% suggested their attitude was positive, and 26% were indifferent. Four main themes exerted an influence on student attitude towards lab. Each theme was identified in responses from all treatment combinations and by at least 20% of the sample. These themes were a) course content, b) the teaching assistant (TA), c) grades, and d) student characteristics. Each of these themes also included two or more sub-themes. The theme of "course content" included the "lab topics," the "lab techniques," and the "thinking skills" employed during lab. The theme of "grades" was closely associated with a sub-theme of "lab reports." The theme of TA was often linked with a sub-theme of "knowing what is expected." Finally, the theme of "student characteristics" included sub-themes of "personal abilities and previous experiences" and "personal desires and/or ambition."

Course Content
Forty percent of participants stated that the course content affected their overall attitude towards biology lab, but its affect varied by individual. Lab topics were most often cited as having an influence on attitude; however, scientific thinking skills and lab techniques were cited by several individuals. Some participants felt the lab topics were "interesting" which contributed to their positive attitude while others felt the topics were "dull and rather mundane" which negatively influenced their attitude.

Sixty-seven percent of participants stated that "course content" influenced their perception of the usefulness of biology lab. Some participants felt that specific lab techniques such as pipetting, microscopy, streaking Petri plates, or working with particular organisms such as bacteria were most useful. One participant said, "We are beginning to do gram-staining and this will be useful if I ever do clinical work or research." Others felt that thinking skills such as reasoning, problem-solving, or communication skills were important while others discussed scientific thinking skills such as hypothesizing, designing experiments, or making conclusions. One participant stated that, "Critically thinking and the process of putting together conclusions based on observations/data" was most useful. Participants generally believed course content would be directly useful to their career.

Teaching Assistant
Forty-six percent of participants indicated that their TA influenced their overall attitude towards biology lab. The TA influenced attitude in both positive and negative ways. Student

attitude was negatively affected if the TA was perceived as "disorganized" or "incompetent." One student said, "My instructor has no clue what she is doing and on top of that I can barely understand her." Attitude was also negatively affected if the TA did not provide enough instruction or did not explain things thoroughly. A student stated, "Many times, I am unsure of what the teacher expects out of me." Conversely, attitude was positively affected if the TA was "nice," "reasonable," or considered "good." One student said, "The TA is very interesting and enthusiastic about everything she says. It makes the class very enjoyable." Several participants mentioned that their TA was the most important factor influencing their attitude.

Twenty-six percent of participants said the TA directly influenced their confidence in biology lab. Again, the TA was both a positive and negative influence on confidence and "good" TAs were perceived as having clear expectations while "bad" TAs were unclear. Some participants made comments that TA grading practices affected confidence, and that "hard" or "harsh" grading negatively affected attitude while easy grading positively affected attitude. Participants also noted that TA feedback boosted confidence, as did help or assistance in lab or on lab reports. One student said, "I feel very confident because my teacher will help me whenever I need it." Conversely, a lack of feedback or assistance negatively affected confidence. As another student articulated, "I have not felt confident in the lab. I feel that if I ask my TA a question regarding the quality of an experiment she will just say that will work and not make me confident in what I am doing is right." A lack of understanding almost always negatively influenced confidence.

Thirty-one percent of participants stated that "knowing what is expected" influenced their confidence, and either directly or indirectly implicated their TA as responsible for setting these expectations. One participant said, "My TA who has a hard time of making his points clear enough for the class to understand strongly influences my lower confidence in the lab itself." Conversely, some participants felt that their TA positively affected their confidence by providing explicit directions and assistance. One such participant said, "Our teacher emails us important things for our assignments, posts things on blackboard to help us, and sends us pointers and tips for doing our assignments." Most participants who commented on the clarity of expectations felt that if they knew what to do, they could do it.

Grades

Twenty-three percent of participants said grades were a factor which influenced their overall attitude towards biology lab. Many students complained about the grades they received, saying that grading was unfair or too hard. One participant said, "I feel like I work very hard on my lab reports after working hard during the labs, yet receive low grades without explanation." Others felt that grading was not consistent and that expectations were unclear. One such participant said, "It seems like something that I did right on a previous lab will be marked as wrong in an upcoming lab." In general, the theme of grades had a negative influence on attitude.

Forty-two percent of participants said that grades influenced their confidence in biology lab. Confidence was generally positively correlated with grades received and poor grades undermined confidence while good grades increased confidence. One participant said, "I feel that my scores give me confidence in being successful in the lab." On the other hand, another participant said their confidence suffered because of grades they received. Several students made comments suggesting that grades should equal the effort they exerted on the assignment.

Forty-eight percent of participants said that grades were the primary factor influencing their level of motivation to overcome challenges and 53% percent stated that lab reports were the greatest challenge in lab. Several aspects of lab reports were cited by participants as being especially challenging, including getting the correct results, knowing what the TA wants, properly formatting tables, figures, and citations, and writing the actual report. One participant said, "The greatest challenge is mastering a perfect lab write up." Most participants said they were "highly" or "very" motivated and that getting good grades on lab reports drove their level of motivation. One participant said, "I am motivated to overcome these challenges because I want a good lab grade." While many participants felt grades were their primary source of motivation, others stated they were intrinsically motivated to overcome the challenges of lab.

Student Characteristics

Thirty-nine percent of participants said their own ambition or personal aspirations influenced their motivation to overcome the challenges of lab. Regardless of their major or career aspirations, some participants made comments suggesting they were intrinsically motivated. One participant said, "My strong drive to succeed definitely influences my level of motivation." These same participants, however, did not discount the importance of grades.

Twenty-five percent of participants stated that their personal abilities or prior experiences influenced their confidence in lab. Some individuals felt that their success in lab was a function of the effort they put into lab. One said, "I feel confident that I will be able to succeed in lab because I do all of my work correctly and I pay very close attention in lab." Another stated, "I think I am a good writer and I understand scientific concepts easily, which has allowed me to do well in lab." Participants who had AP biology in high school or previous lab courses felt these experiences positively affected their confidence in lab.

Discussion

Instructional Models and Student Attitude

The results of this study suggest that instructional model was not as important as other factors in driving student attitude. This was evidenced by both the lack of a significant difference in RCA among the treatment combinations as well as the almost complete lack of comments making mention of the instructional model in the open-ended student survey responses. Because confidence varied significantly among lab sections, it could be inferred that factors such as perception of the instruction provided by the TAs, including their grading practices, may have been more important drivers of changes in attitude in this study. Quality of instruction was cited by students as the most important component of student satisfaction on end-of-semester evaluations of one reformed biology course (Armbruster *et al.*, 2009). Student responses in the qualitative portion of this study also strongly suggested that instruction superseded the curriculum when it came to student attitude.

Attitude decreased from the pre to post tests in each of the four instructional model treatment combinations for all three aspects of attitude measured in this study, although there were considerable differences among lab sections within each treatment combination. This contradicts the findings of Ajewole (1991) and Lord and Orkwiszewski (2006), who identified more positive attitudes among students who participated in IN-based biology courses as compared to students in expository labs. While Berg et al. (2003) also noted an increase in attitude as a result of IN instruction, they also reported student frustration with the open-IN format of the reform lesson. In this study, since student attitude decreased in all instructional treatments, this change was likely to be more related to the course than it was to the instructional model.

The course being investigated was a first semester introductory biology course and most students were freshmen who did very well in high school, but who may or may not have been prepared for the rigors of a college course (Clark, 2005). Stupinsky, Renaud, Daniels, Haynes, and Parry (2008) found many first year students to perceive a lack of "academic control" as they transition to college courses and lower grades were associated with a perceived lack of control. While these authors did not investigate student attitudes, the relationship between achievement and attitudes suggests that attitude may have suffered if students did not perform to their own expectations. Significantly more positive attitudes have resulted from IN style activities compared to traditional instruction in the second part of a two-course sequence (Luckie, Maleszewski, Loznak, & Krha, 2004) and it is possible that if this project had been implemented in the second semester course of the sequence the attitude results may have been different. It is also possible that an implementation of the same approach in a non-majors course with less science career-oriented students may have generated different results.

Another study comparing traditional and IN based biology labs found that students in the traditional instructional model had higher confidence than students in the revised IN treatment (Brickman *et al.*, 2009). These authors speculated that students in the traditional treatment had a false sense of confidence instilled by participation in a verification lab and that students in the IN treatment were resistant to aspects of IN instruction. This could explain why there was a slight, albeit insignificant increase in confidence in the EX+ER treatment combination in our study, perhaps indicating that confidence could be more related to instructional model than other attitude aspects.

While it is not possible to confirm this speculation, it may be that despite the apparent uniform decline in attitude in all treatments, that different factors caused decreases in different treatments. For example, student attitude may have decreased in the expository treatment because students found the lab simplistic or boring, while student attitude in the IN treatment may have suffered because there was no predetermined answer to the labs or because their TA did not directly answer their questions. Brickman et al. (2009) identified such a situation in their study; they found that students in the inquiry treatment disliked the uncertainty associated with the inquiry experience while students in the non-inquiry treatment expressed dissatisfaction with the lack of genuine learning. Therefore, it is possible that despite the similar changes in attitude, there were different drivers of attitude in each treatment.

In the qualitative portion of the study, very few student comments were made in reference to the different instructional models and none were made regarding ER pedagogy. This lack of student comments regarding the instructional models may reflect a lack of awareness regarding different approaches to lab instruction. Chatterjee et al. (2009) noted that less than half of the students in an IN chemistry lab could differentiate between open and guided IN labs. Given this lack of curricular awareness, students may have interpreted differences among labs as a personal choice of the TA versus a planned reform to the curriculum. It has been suggested that students should be made explicitly aware of instructional strategies such as IN labs so that they understand the impacts these have on the role of the student and instructor (Doyle, 2008).

Factors Influencing Student Attitude
Qualitative results indicated that four main factors influenced student attitude: content, the TA, grades, and the students themselves (Figure 2 Of the four themes, however, only the factors of TA, grades and student characteristics were linked to attitude characteristics that varied by lab section. Course content was linked to students' perceptions of course usefulness, but this did not vary by treatment combination or lab section.

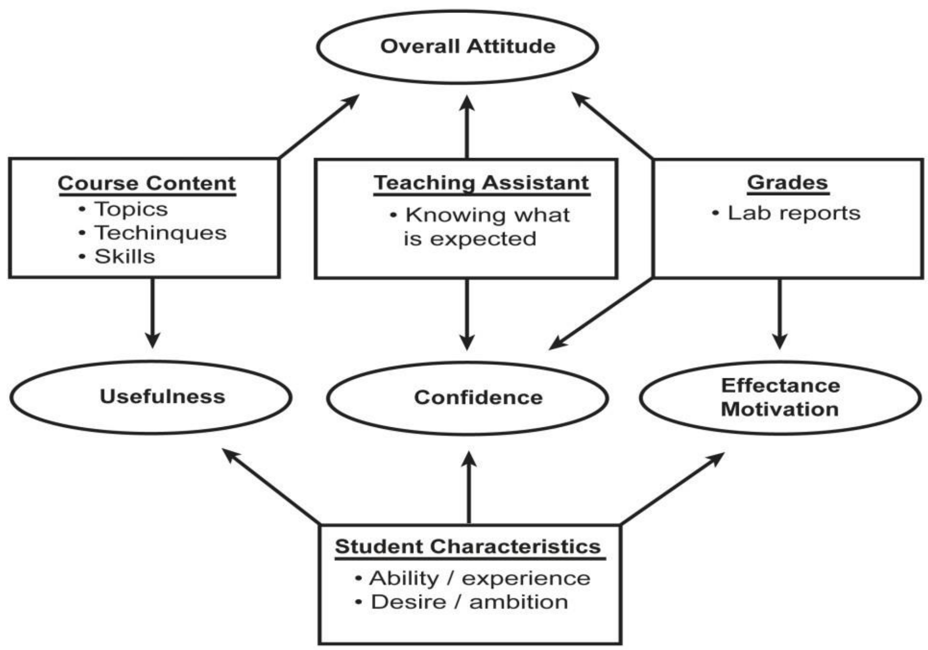

Figure 2. Model of attitudinal sub-aspects (ovals) and themes reported by students to influence attitudinal sub-aspects (rectangles) on open-response surveys. Arrows indicate which themes influenced which attitudinal sub-aspect.

Students' personal characteristics were identified as a factor affecting attitude in this study. It has been suggested that extrinsically motivated students may have more difficulty with IN than intrinsically motivated students, in part because these students may have different learning goals (see review by Glynn & Koballa, 2006). Other studies found similar results, where students with "positivist" (e.g., "there is a right answer") scientific epistemologies struggled more than students with "constructivist" (e.g., "scientific knowledge is tentative") in IN learning experiences (Wallace, Tsio, Calkin, & Darley, 2003). Further research on how to introduce instructional models such as IN to students with different learning goals may decrease student resistance to reformed instructional models.

The TA had both a positive and negative effect on student confidence and overall attitude. These findings agree with those of Haladyna et al. (1982) who reported that the instructor was the single most important factor affecting student attitude. Clarity of instruction and willingness to help were described by students in this study as positive characteristics of a

TA, while negative characteristics included a lack of clarity, inconsistencies in grading, and lack of support. Marbach-Ad, Seal, and Sokolove (2001) found that student perceptions of what constitutes a good TA included enthusiasm, approachability, and good communication skills. Another study found that two TA characteristics positively related to student confidence were willingness to interact with students and the ability to convey what is expected (Hartnett, Romcke, & Yap, 2003). While some of these attributes reflect the individual TAs' personality, clarity of instruction does not. Many of the participants in our study made comments that knowing what was expected of them strongly influenced their confidence. These comments came from participants in all treatment combinations, indicating that TAs differed in their ability to convey goals and expectations and align them with instruction. If this was indeed a major driver of student attitude, then differences among individual TAs in their ability to inspire and motivate students (regardless of treatment combination) could outweigh differences among instructional models.

In this study, assessment and specifically lab reports clearly dominated participants' lab experiences, possibly because they were perceived as a large part of the lab grade. The two predominant themes related to lab reports were grades and the TA. Grades seemed to be a primary goal for most students and relatively few students discussed learning as more important than grades. In addition, many comments dealt specifically with TA grading practices, possibly because students equated their lab reports and grade with whether they thought the TA was a fair grader. It has been noted that although reformed instructional models are increasingly being employed in introductory labs, assessment techniques have not generally been changed (Moskovitz & Kellogg, 2011) and this can lead to confusion among students and TAs about what learning outcomes are valued in the course. If grades received were the primary driver, then once again, this would vary by TA because TAs were responsible for grading the student lab communications. Student attitude would therefore vary by TA and not the instructional model they underwent.

Implications

Although there was little evidence that different instructional models directly influenced student attitude towards biology lab in this study, course content, the TA, grades, and student characteristics did affect student attitude. Whether attitude was positively or negatively impacted by each of these factors depended in part upon individual students' personal characteristics, especially their sources of motivation. Students with particularly extrinsic motivation seemed to perceive the lab reports and grades received as the most important aspect of lab, and content as useful only if it fit with preconceptions of their career. Many of these students implicated their TA as the source of the content and grades, thus directly linking them with their attitude. Other students found ways to connect lab content with lecture content, appreciated the instruction and grading of the TA, and felt motivated to meet the challenges of the lab. This suggests that attitudinal response to reformed instructional models will rely on improving the attitudes of specific subsets of the student population, specifically those who are extrinsically motivated. The most challenging aspect of this situation is that the TAs are the interface between the reformed curricula and the students who may be unaccustomed to such instructional models. For this reason, it is crucial that course coordinators explicitly inform the TAs of the instructional goals of the curriculum and TAs effectively convey these intentions to the students.

An important caveat in this study is that only a single semester was analyzed. By tracking students through a second semester, it may have been possible to isolate differences between changes in attitude resulting from simply participating in a first semester college course and changes due to different instructional models. Another factor in the study was that the reform efforts were concentrated solely on the lab sections and not on the lecture portion of the course. The lab only counted 25% of the total grade for the course and students may have considered it less important to fully engage with the IN aspects of the lab given its lesser importance to their grade. Subsequent studies which involve whole course revisions, especially the lecture portion, may elicit different attitudinal responses from the students. It is important to note, however, that such whole course revisions are exceedingly difficult to coordinate in large enrollment courses taught in multiple lecture sections with different professors and multiple TAs.

Teaching that employs reformed instructional models poses several unique challenges such as leading collaborative discussions with undergraduates (Jenson, Farrand, Redman, Varcoe, & Coleman, 2005) and getting students to participate in IN activities (Cianciolo, Flory, & Atwell, 2006). It has also been found that not all TAs are equally prepared to handle these challenges. Shannon, Twale, and Moore (1998) concluded that TA effectiveness was related to prior teaching experience and that current TA training programs were not effective in meeting the needs of first time TAs. Training programs should therefore include instruction on providing clear expectations (Duran et al., 2004), effective communication skills (Roach, 1999), consistency in grading, and giving better feedback (Gibbs & Simpson, 2004). Helping TAs meet these challenges may in turn differentially improve student attitude toward reformed teaching methods.

Conclusion

This study highlights the complexities of implementing reformed instructional strategies in introductory college biology labs. The findings of this study are unique in that both quantitative and qualitative data suggest that the relationship between attitude and instructional model in lab courses are mediated primarily by the students themselves and the TAs responsible for instruction. This implies that reform efforts may be complicated by the interactions between course objectives, students' personal characteristics, and TAs responsible for the delivery of instruction. Instructors implementing reforms would be well advised to critically assess linkages among these three components of the revision process so that the likelihood of successful reform implementation may be maximized.

Acknowledgements
The authors thank the student participants, graduate students, and their collaborators at Miami University, in Oxford, Ohio, and acknowledge support from Miami University and from the National Science Foundation grant no. DUE-0736786.

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